Global Precipitation Measurement (GPM) Project

Performance Specification for the GPM Medium Sun Sensors

Goddard Space Flight Center
Greenbelt, Maryland

National Aeronautics and Space Administration

CM FOREWORD

This document is Global Precipitation Measurement (GPM) Configuration Management (CM)-controlled document. Changes to this document require prior approval of the applicable Configuration Control Board (CCB) Chairperson or designee. Proposed changes shall be submitted to the GPM CM Office (CMO), along with supportive material justifying the proposed change. Changes to this document will be made by complete revision.

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CHANGE RECORD PAGE

Version	CCR #	CCR Date	MOD #	MOD DATE	Description	Section Affected
Rev -	100	01/30/09			Baseline	All

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

Table Page

1 SCOPE

This specification describes the electrical, mechanical, operating environment, and verification testing requirements for space-qualified, Medium Sun Sensors for a Goddard Space Flight Center (GSFC) payload, the Global Precipitation Measurement (GPM) Mission.

2 DOCUMENTS AND DEFINITIONS

2.1 *APPLICABLE DOCUMENTS*

The following documents and drawings in effect on the day this specification was signed shall apply to the fabrication and to the electrical, mechanical, and environmental requirements of the Medium Sun Sensors to the extent specified herein. In the event of conflict between this specification and any referenced document, this specification will govern, with the exception of the Statement of Work, GPM-GN&C-SOW-0001, in which case the SOW takes precedence.

The following is a list of the applicable specifications and publications.

Table 2-1 List of Documents

DOCUMENT NUMBER	TITLE	Revision/Date
GPM-GN&C-SOW-0001	GPM Sun Sensor Statement of Work	
GPM-GN&C-LIST-0001	GPM Sun Sensor Deliverable Items List and Schedule	
422-40-01-004	GPM Mission Assurance Requirements	
422-40-03-001	GPM Core Spacecraft Performance Requirements	
JSC-SN-C-005	Contamination Control Requirements for the Space Shuttle Program	

2.2 *DEFINITIONS*

2.2.1 Flight Unit

A Flight Unit is hardware that will be used operationally in space. A Protoflight Unit, described below, is considered a Flight Unit.

2.2.2 Protoflight Unit

A Protoflight Unit is Flight hardware of a new design. It is subject to a test program that combines elements of prototype and flight acceptance verification; that is, the application of design qualification test levels and flight acceptance test durations.

3 REQUIREMENTS

In this document, a requirement is identified by "shall", a good practice by "should", permission by "may", or "can", expectation by "will" and descriptive material by "is". All of the written requirements in this document must apply at the end of spacecraft (SC) life (EOL), as defined in Section 3.5.

3.1 *DESCRIPTION*

MSS eyes will be used to provide sun position information as a key part of the GPM attitude control system.

MSS-38 Ground support equipment (GSE) will enable aliveness testing of the MSS by illuminating the MSS to generate a current output from the MSS during spacecraft Integration and Testing. The GSE will include MSS stimulators and a control panel, which shall meet the requirements as defined in Section 5.0.

3.2 *PHYSICAL CHARACTERISTICS*

3.2.1 Design for Demise

MSS-41 In order to limit debris re-entry survival, the MSS shall satisfy the following two conditions:

(1) melting point below 1000°C, or all linear dimensions below 0.20 m

(2) mass below: 3.0 kg of stainless steel alloys, or 1.0 kg of titanium alloys, or 1.0 kg of beryllium alloys, or 10.0 kg of aluminum alloys, or 1.0 kg of any material with a melting point greater than 1000°C.

The MSS will satisfy these conditions if it meets the mass and envelope requirements in Sections 3.2.2 and 3.2.3.

3.2.2 Mass

MSS-43 Total as delivered MSS mass shall be less than or equal to 500 (g).

3.2.3 Envelope

MSS-45 The MSS shall occupy a space of less than:

height: 127 millimeters (mm); (5.0 inches [in.])

width:127 mm; (5.0 in.)

length:127 mm; (5.0 in.)

For the purposes of clarifying this requirement, the length (L) and width (W) dimensions define the mounting surface. See Figure 3-1.

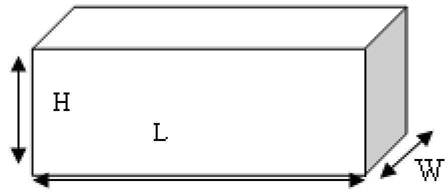


Figure 3-1 Envelope Dimension Definitions

3.2.4 Minimum Resonant Frequency

MSS-57 The MSS shall have a fundamental frequency greater than 100 Hertz (Hz) when hard mounted at the spacecraft interface. Flexures are considered as part of the component. This requirement shall be verified by test during structural sine sweep testing.

3.2.5 Mounting

MSS-59 The package will be hard-mounted on a mechanical surface of the spacecraft structure. Proper fit/alignment of the MSS to the structure shall be inherent in its design, fabrication, and assembly to the structure, through the use of close dimensional control in the location of mounting holes and the use of correct mounting hardware. The mounting interface shall be defined in the Interface Control Document (ICD). The mounting surface shall have a flatness of 0.05 mm per 100 mm (0.006 in. per 12 in.) or better.

3.2.6 External Adjustment

MSS-61 The MSS shall be designed so that no external adjustments are required after start of acceptance or qualification testing.

3.2.7 Finish

MSS-63 All parts should be passivated and external mounting surfaces shall be conductive as defined in Section 3.3.8 (Surface Conductivity.) Aluminum parts shall be finished with iridite per MIL-C-5541, Class 3. Additional coatings may be used with the written approval of the GSFC COTR.

3.2.8 Identification and Marking

MSS-65 Each unit shall be permanently marked with the part number and a unique sequential serial number in the area designated on the Interface Control Drawing in a manner to be approved by the GSFC Contracting Officer's Technical Representative (COTR).

3.2.9 Fastener Locking

MSS-565 All threaded fasteners used in MSS shall employ a locking feature.

3.2.10 Polarity, Orientation, and Position Testing

MSS-570 The polarity of the MSS shall be verified by test or inspection. This means that it shall be verified that stimulation of the MSS will create output currents which indicate sun angles with the proper sign and for the proper axis. MSS orientation and position shall be verified after installation on the GPM spacecraft.

3.3 *ELECTRICAL CHARACTERISTICS*

MSS-67 The electrical interface configuration shall meet the overall requirements of this specification.

3.3.1 Power Interface

MSS-69 The MSS shall be a current source and shall not require or consume any power.

3.3.2 Connectors

MSS-71 Electrical connections shall be made to terminals on the MSS or to a connector on the MSS. This shall be defined in the Interface Control Document.

3.3.3 Output Level

MSS-73 Each MSS eye shall have a peak output between 1.2 milliamperes and 4.0 milliamperes, corresponding to full solar illumination on the boresight axis. The boresight axis shall be normal to the mounting surface of the MSS.

3.3.4 Field of View

MSS-75 Each MSS shall be capable of providing an output when the sun is within a conical FOV with a half-cone angle of magnitude 17.5 degrees. The tolerance on the half cone angle magnitude is +/- 2.5 degrees. This FOV will limit the effect of Earth albedo.

3.3.5 Accuracy

MSS-77 The MSS output (current levels) shall be used as input for the MSS software algorithms, which shall be provided by the vendor. The algorithms shall output two axes of data sufficient to define an MSS-to-Sun vector. The calculated position of the Sun shall be within 2.0 degrees (per axis, 3 sigma) of the actual position of the Sun.

3.3.6 Alignment

MSS-79 The boresight axis of the MSS shall be perpendicular to the MSS mounting surface within the tolerances listed below:

Placement	0.2 degrees (3 sigma)
Knowledge	0.1 degrees (3 sigma)
Stability	0.2 degrees (3 sigma)

3.3.7 Bonding or Mating

MSS-84 The primary mating method for the MSS shall be the metal-to-metal contact between component mounting feet (or baseplate) and the GPM structure. Mating (electrically bonding) surfaces should be free from nonconductive finishes and should establish sufficient conductive contact surface area such that the electrical direct current (DC) resistance between the mating surface of the MSS and the mating structure shall not exceed 10 milliohms DC.

MSS-85 If the MSS is to be mounted on a composite or other low conductive material, a grounding strap shall be attached from the component chassis to an Orbiter conductive structure.

3.3.8 Surface Conductivity/External Discharge Protection

MSS-87 The component shall meet the following requirements in order to survive the low Earth orbit charging environment.

MSS-88 External surfaces >6 centimeters squared (cm2) shall be conductive with a resistivity of less than 1e9 ohms per square (ohms/sq.) and grounded to the structure, so that charge can bleed from that surface faster than the charge can build up on that surface.

MSS-89 Insulating films such as Kapton and other dielectric materials on the external surface shall be less than 5 mil thick and shall be assembled to minimize surface charge build-up and grounded to bleed surface charge.

MSS-90 A comprehensive list of non-conductive surfaces shall be maintained and reviewed periodically throughout the MSS development to identify any new electrostatic discharge (ESD) threats to the spacecraft.

3.3.9 Software Algorithm Updates

MSS-92 Software algorithms, if applicable, shall be subject to proper Configuration Management (CM) at the vendor. All updates to the software algorithms shall be provided by the vendor at the time the updates are entered into the CM system.

3.3.10 Magnetic Requirements

MSS-568 The magnetic flux density of the MSS shall be no more than 100 nanoTesla (6 milligauss) when measured 1 meter from the item.

3.4 *LIFE REQUIREMENTS*

3.4.1 Mission Life

MSS-95 Component orbit life shall be a minimum of 38 months.

3.4.2 Shelf Life

MSS-97 The component shall not suffer any degradation in performance when stored for five years when packaged using agreed-to procedures.

3.5 *ENVIRONMENTAL REQUIREMENTS*

MSS-99 The component shall be designed to withstand (without degradation of specified performance) the operational and non-operational environments specified in the following section.

3.5.1 Static Loads

MSS-101 The component shall demonstrate its ability to meet its performance requirements after being subjected to limit loads of 36 g. Loads are to be applied independently in each axis.

3.5.2 Vibroacoustic Loads

MSS-105 The MSS shall be capable of withstanding the random vibration levels shown in Table 3-1 and the sine vibration levels of Table 3-2, individually applied to three mutually orthogonal axes.

Table 3-1 Random Vibration

Duration of Test	FREQUENCY (HZ)	Acceptance (Flight) LEVELS (g2/Hz)	Qualification (PROTOFLIGHT and PROTOTYPE) LEVELS (g2/Hz)
Qualification: 2 minutes per axis Acceptance: 1 minute per axis	20	0.013	0.026
	20-50	+6 dB/oct	+6 dB/oct
	50-800	0.080	0.160
	800-2000	-6 dB/oct	-6 dB/oct
	2000	0.013	0.026
	Overall Grms	10.0 Grms	14.1 Grms

MSS-138 The above random environment is appropriate for components weighing 22.7 kilograms (kg) (50 pounds [lbs]) or less. This environment will be updated with random vibration analysis. Note that for lightweight components, the highest design loads may be from this random vibration environment. The contractor shall perform random vibration analysis along with static loads analysis. Please see NASA-HDBK-7005 and NASA-STD-7001 for more information.

Table 3-2 Sine Vibration Test Levels

	Acceptance		Qualification/Protoflight	
Axis	**Frequency (Hz)**	**Level (g)**	**Frequency (Hz)**	**Level (g)**
Axial	5-50	6.4	5-50	8.0
Lateral	5-50	6.4	5-50	8.0

MSS-163 Sine vibration levels may be notched to not exceed 1.25 times the design limit load taken from Section 3.5.1. These levels will be updated as coupled-loads analysis (CLA) data becomes available. The MSS shall test for this environment up to 50 Hz and analyze from 50 to 100 Hz.

3.5.3 Shock

MSS-165 The maximum expected shock environment at the component interface is shown in Figure 3-3 below. The component shall be assessed for damage due to shock based on shock sensitivity or proximity to shock sources. If the component is not considered by GSFC to be susceptible to the shock environment, shock testing can be deferred to the level of assembly that allows for actuation of the actual shock-producing device.

If the component is considered to be susceptible to the shock environment, the Contractor may need to perform a shock test to demonstrate that the item can survive the predicted shock environment. The GPM Project will assess the final shock environment based on specific component location.

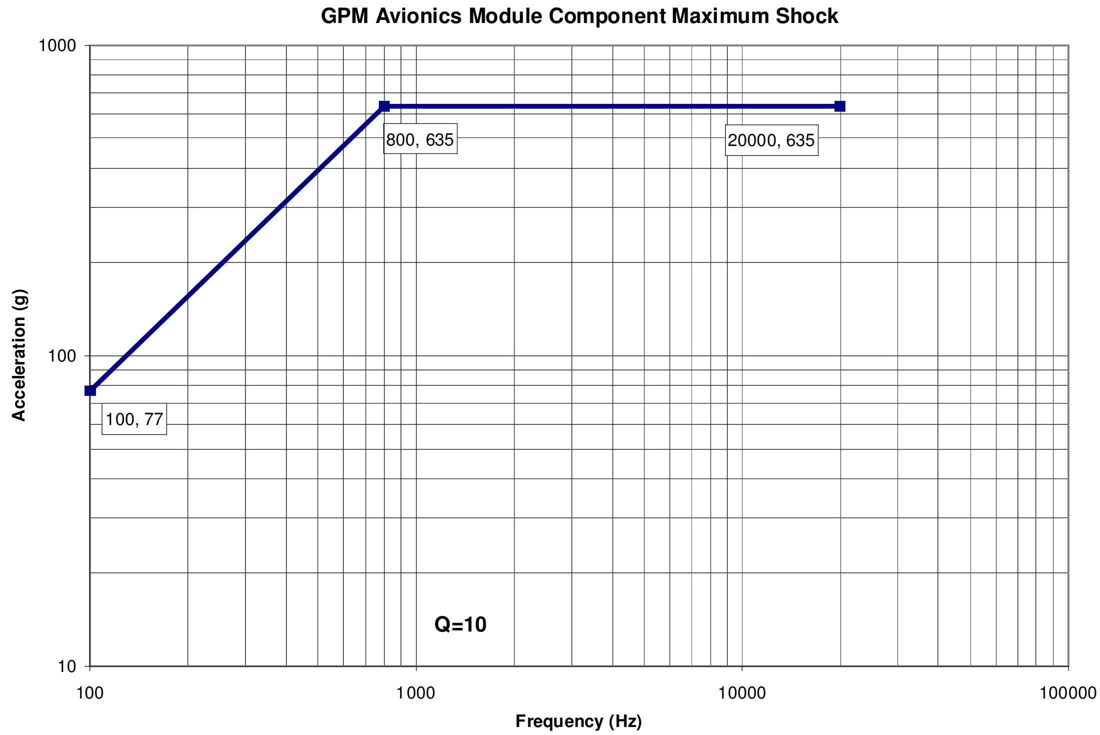


Figure 3-2 Component Shock Specification

3.5.4 Acoustic

MSS-170 The MSS shall be designed to meet its performance requirements after being subjected to the acoustic environment listed in Table 3-3. The sound pressure levels are based on the specified launch vehicle only. For small, acoustically insensitive components such as the MSS, acoustic testing prior to S/C integration is not required. For these components, base drive qualification or protoflight random vibration testing shall be required for high frequency verification.

Table 3-3 Acoustic Levels for HIIA-202

Full Octave Frequency Band (Hz)	Flight/Acceptance Sound Pressure Level (dB)	Protoflight/Qual Sound Pressure Level (dB)
31.5	125	128
63	126.5	129.5
125	131	134
250	133	136
500	128.5	131.5
1000	125	128
2000	120	123
4000	115	118
8000	113	116
OSPL	**137.5**	**140.5**

3.5.5 Thermal

MSS-218 The MSS shall be capable of operation with interface temperatures defined in Table 3-4. Unless specifically approved by the COTR, the thermal design shall dissipate heat conductively through the mounting interface, which should be assumed to be at the qualification temperatures.

Table 3-4 Temperature Limits at Mounting Interface

Condition	**Cold Limit (degrees C)**	**Hot Limit (degrees C)**
Operational Temperatures	-10	+65
Acceptance Temperatures	-15	+70
Qualification Temperatures	-20	+75
Survival Temperatures (each unit must turn on at these extremes but does not have to meet performance requirements)	-30	+85

3.5.6 Vacuum

MSS-242 The MSS shall be capable of meeting all performance requirements of Section 4.3 at ambient as well as when exposed to a vacuum environment of 1 x 10-5 Torr, or less.

3.5.7 Atomic Oxygen

MSS-244 Materials used in the construction of the MSS assembly shall not generate contamination products resulting from the interaction with an atomic oxygen environment. All operational requirements shall be satisfied during exposure to the atomic oxygen environment at 400 +/- 10 kilometers (km) circular orbit for the entire mission lifetime. The expected atomic oxygen fluence for GPM is 1.464e22 atoms of Atomic Oxygen (AO) per square centimeter (cm2). This is based on a 3-year mission, per the GPM Core Observatory Performance Requirements.

3.5.8 Radiation

MSS-246 No effect due to total ionizing dose (TID) may cause permanent damage to or degradation of the MSS. The MSS shall be capable of fulfilling its intended application after accumulated exposure based on shielding provided only by the Contractor. The GPM spacecraft will not provide any shielding for the MSS. As a point of reference only, for a five year mission with shielding of 100 mils, the TID (with 2x design margin) is 10 krad-Si. Other radiation requirements which shall be met are contained in the GPM Core Observatory Performance Requirements (GPM 422-40-03-001).

3.5.9 Humidity

MSS-248 The MSS shall be capable of meeting the requirements herein during and after exposure to 20 to 70% relative humidity for 2 years.

3.5.10 Venting

MSS-250 All MSS shall be vented to prevent pressure buildup during the ascent phase of launch. The MSS shall survive external depressurization from one atmosphere (atm) to 10-5 Torr in 60 seconds.

MSS-251 GPM components not having a minimum of 0.25 square inches of vent area for each cubic foot volume, shall demonstrate the ability to survive the venting rate. If analysis is required, the venting analysis must indicate a positive structural margin at loads equal to the maximum expected pressure differential during launch, with a Factor of Safety of 2.0 applied to the loads.

3.5.11 Contamination Control

MSS-253 The contractor shall establish cleanliness requirements to minimize performance degradation and delineate the approaches to meet the GPM Project requirements.

3.5.12 Cleanliness

MSS-255 All hardware shall be fabricated in Class 100K or better cleanrooms per ISO 14644.

MSS-573 All hardware shall be verified to be visibly clean highly sensitive (per JSC-SN-C-005) with a blacklight inspection.

MSS-574 External cleanliness shall be verified prior to or upon delivery to Goddard. If the external cleanliness is not met, the vendor or CCE will clean, re-inspect, and re-verify its cleanliness.

4 VERIFICATION REQUIREMENTS

MSS-257 The contractor shall conduct a verification program that demonstrates the hardware design is qualified and meets all requirements contained in this document. The contractor shall provide a verification matrix defining the method of verification for each specific requirement of this document. Verification methods include inspection, analysis, test or a combination of these techniques.

4.1 *INSPECTION*

Verification by inspection includes visual inspection of the physical hardware, a physical measurement of a property of the hardware, or the documentation search demonstrating hardware of an identical design has demonstrated fulfillment of a requirement.

4.1.1 Visual Inspection

Visual inspection of the physical hardware by a customer appointed qualified inspector.

4.1.2 Physical Measurement

Physical measurement of hardware property (i.e. mass, dimensions, etc.) demonstrating the hardware meets specific requirement.

4.1.3 Documentation Search

MSS-265 Verification of requirements based on similarity shall include supporting rationale and documentation and shall be approved by the GSFC COTR.

4.2 *ANALYSIS*

Verification of performance or function through detailed analysis, using all applicable tools and techniques, is acceptable with GSFC COTR approval.

4.2.1 Factors of Safety

MSS-269 Structural analyses shall be performed to show positive margins of safety based on the factors of safety show in Table 4-1.

Table 4-1 Factors of Safety

Type of Hardware	Design Factors of Safety	
	Yield	Ultimate
Tested Flight Structure - metallic	1.25	1.4
Tested Flight Structure - beryllium	1.4	1.6
Tested Flight Structure - composite(1)	N/A	1.5
Tested Flight Structure - pressurized glass(2)	N/A	3.0
Tested Flight Structure - unpressurized glass	N/A	3.0
Untested Flight Structure - unpressurized glass	N/A	5.0
Untested Flight Structure - metallic only	2.0	2.6

(1) All composite structures must be tested to 1.25 x limit loads

(2) Pressurized glass structures must be tested to 2.0 x limit loads

4.3 *TEST*

Represents a detailed test of performance and/or functionality throughout a properly configured test setup where all critical data taken during the test period is captured for review.

MSS-310 Performance parameter measurements shall be taken to establish a baseline that can be used to assure that there are no data trends established in successive tests that indicate a constant degradation of performance within specification limits that could result in unacceptable performance in flight.

4.3.1 Test Factors

MSS-312 The following test factors and durations, shown in Table 4-2, shall be used for prototype, protoflight, and flight hardware. The hardware definitions are included in the General Environmental Verification Standards (GEVS) for Flight Programs and Projects (GSFC-STD-7000).

Table 4-2 Test Factors and Durations

Test	Qualification	Protoflight	Acceptance
Structural Loads Level Duration Centrifuge Sine Burst(1)	1.25 X Limit Load 1 Minute 5 Cycles Full Level	1.25 X Limit Load 30 Seconds 5 Cycles Full Level	Limit Load(2) 30 Seconds 5 Cycles Full Level
Acoustic Level Duration	Limit Level +3dB 2 Minutes	Limit Level +3dB 1 Minute	Limit Level 1 Minute
Random Vibration Level Duration	Limit Level +3dB 2 Minutes/Axis	Limit Level +3dB 1 Minute/Axis	Limit Level 1 Minute/Axis
Sine Vibration Level Sweep Rate(3)	1.25 X Limit Level 2 Octaves/Minute/Axis	1.25 X Limit Level 4 Octaves/Minute/Axis	Limit Level 4 Octaves/Minute/Axis
Shock Actual Device	2 Actuations	2 Actuations	1 Actuations

MSS-345 (1) Sine burst testing shall be done at a frequency sufficiently below primary resonance as to ensure rigid body motion.

(2) All composite structures must be tested to 1.25 x limit loads.

MSS-347 (3) Unless otherwise specified these sine sweep rates shall apply.

4.4 *TEST RESTRICTIONS*

4.4.1 Failure During Tests

MSS-350 The test shall be stopped if equipment fails during testing in cases where this failure will result in damage to the equipment. Otherwise, the test shall be completed to obtain as much information as possible. No replacement, adjustment, maintenance, or repairs are authorized during testing. This requirement does not prevent the replacement or adjustment of equipment that has exceeded its design operating life during tests, provided that after such replacement, the equipment is tested as are necessary to assure its proper operation. A complete record of any exceptions taken to this requirement shall be included in the test report.

4.4.2 Modification of Hardware

MSS-352 Once the formal acceptance test has started, cleaning, adjustment, or modification of test hardware shall not be permitted.

4.4.3 Re-Test Requirements

If any event, including test failure, requires that a component be disassembled and reassembled, then all tests performed prior to the event must be considered for repeat. If the unit has multiple copies of the same build, then all units must be examined to determine if the problem is common. If all copies require disassembly for repair, then each must receive the same test sequence.

4.5 *REQUIRED VERIFICATION METHODS*

The following measurements, tests, environments, and inspections are required for each MSS to provide assurance that the MSS meets specified performance, functional, environmental, and design requirements. Each test or demonstration is described below.

a. Weight and Envelope Measurements

b. Initial Alignment (if necessary), Performance and Functional Tests

c. Shock Test (if necessary)

d. Loads Test (Prototype/Protoflight only)

e. Sine Vibration

f. Random Vibration

g. Thermal Vacuum

h. Final Alignment (if necessary), Performance and Functional Tests

4.5.1 Weight and Envelope Measurement

MSS-366 Measurement of the weight and envelope of the MSS shall be made to show compliance with specified requirements and provide accurate data for the mass properties control program.

4.5.2 Performance Tests

MSS-368 The MSS shall be tested to demonstrate compliance with performance requirements, including alignment if necessary. Performance Tests are detailed functional tests conducted under conditions of varying internal and external parameters with emphasis on all possible modes of operation for the component. A Performance Test shall be conducted at the beginning and end of each acceptance test. Functional Tests are abbreviated Performance Tests done periodically during or following the component environmental testing in order to show that changes or degradation to the component have not resulted from environmental exposure, handling, transporting, or faulty installation.

4.5.3 EMI/EMC

EMI/EMC testing is not required for the MSS.

4.5.4 Load Tests

MSS-372 Structural design loads per the levels in Section 3.5.1 shall be applied to prototype or protoflight hardware. There is no requirement to strength test flight hardware that has already been strength tested through a prototype or protoflight program (i.e., there is no “acceptance level” strength test requirement for flight hardware).

Structural Loads testing can be verified by performing either a fixed frequency Sine Burst test, or a series of static loads pull tests.

No permanent deformation may occur as a result of the loads test, and all applicable alignment requirements must be met following the test. Components that require alignment will have an alignment check following loads testing. A performance test will be conducted to verify that no damage occurred due to the loads test.

4.5.4.1 Sine Burst

A simple Sine Burst test following the random vibration test in each axis is a convenient method to conduct a structural loads test. This test applies a ramped sine input at a sufficiently low frequency such that the test item moves as a rigid body. An analysis is required to show that a base drive Sine Burst test will not cause over-test or under-test in some areas of the structure.

Test Duration: 5 cycles of full level amplitude.

4.5.4.2 Static Pull

Static pull tests are another method to perform loads testing and can be applied at flight interfaces in a static test facility. The loads can be applied either as component loads applied simultaneously, or the single resultant vector load can be applied to the test point. Strain gages are generally positioned around the test point to verify deflection predictions from the analytical model.

Test Duration: 30 seconds

4.5.5 Random Vibration

MSS-382 The MSS shall be subjected to a random vibration test along each axis to the appropriate levels shown in Section 3.5.2. The test item shall be mounted to the test fixture as it would be mounted to the spacecraft. A functional test shall be performed before the start of testing and after a test in each axis.

Prior to the test, a survey of the test fixture/exciter combination will be performed to evaluate the fixture dynamics and the proposed choice of control accelerometers.

MSS-384 The Test Duration for the test shall be 1 minute per axis for Acceptance and Protoflight Tests and 2 minutes per axis for Prototype Tests.

4.5.6 Sine Vibration

MSS-386 The MSS shall be subjected to swept sine vibration testing to the appropriate levels in Section 3.5.2. The sweep rate shall be 4 octaves/minute for Acceptance and Protoflight Tests and 2 octaves/minute for Qualification Tests.

The Signature Sine sweep will be conducted on each component before and after vibration testing in each axis. This test is a tool to verify no change in structural integrity from testing and to verify the primary resonant frequency meets requirements of Section 3.2.4.

4.5.7 Thermal Vacuum Test

MSS-389 Each component shall be cycled a total of eight (8) times at the component level. During these tests, chamber pressure shall be less than 1.33 X 10-3 Pa. (1 X 10-5 torr).

4.5.7.1 Chamber Pump-Down

Because the MSS output will not be used during launch, the MSS do not need to be stimulated during chamber pump-down.

4.5.7.2 Temperature Transitions

MSS-393 Transitions from cold to hot conditions increase contamination hazards because material that has accreted on the chamber walls may evaporate and deposit on the relatively cool test item. Transitions will be conducted at rates sufficiently slow to prevent that from occurring. Testing shall start with a hot soak and end with a hot soak to minimize this risk.

4.5.7.3 Hot/Cold Turn-On Demonstration

MSS-395 MSS operation shall be verified twice after exposure to hot and cold survival temperatures. See Figure 4-1.

4.5.7.4 Electrical System Performance

The electrical system and performance will also be verified at minimum and maximum temperatures and during temperature transitions.

Functional tests or performance tests will be conducted during the hot and cold soaks. Immediately following the component thermal vacuum cycling will be the bakeout phase to eliminate volatiles. See Figure 4-1.

First 2 cycles (all units) Increase temperature to Survival Limit for 1 hour, then return to Test Temperature, verify that component operates, then verify nominal performance once the component has reached the qualification temperature. Begin hot soak.

During the transition from warm to cold, decrease temperature to Survival Limit for 1 hour, then return to Test Temperature, verify that component operates, then verify nominal performance once the component has warmed to the qualification temperature. Begin cold soak.

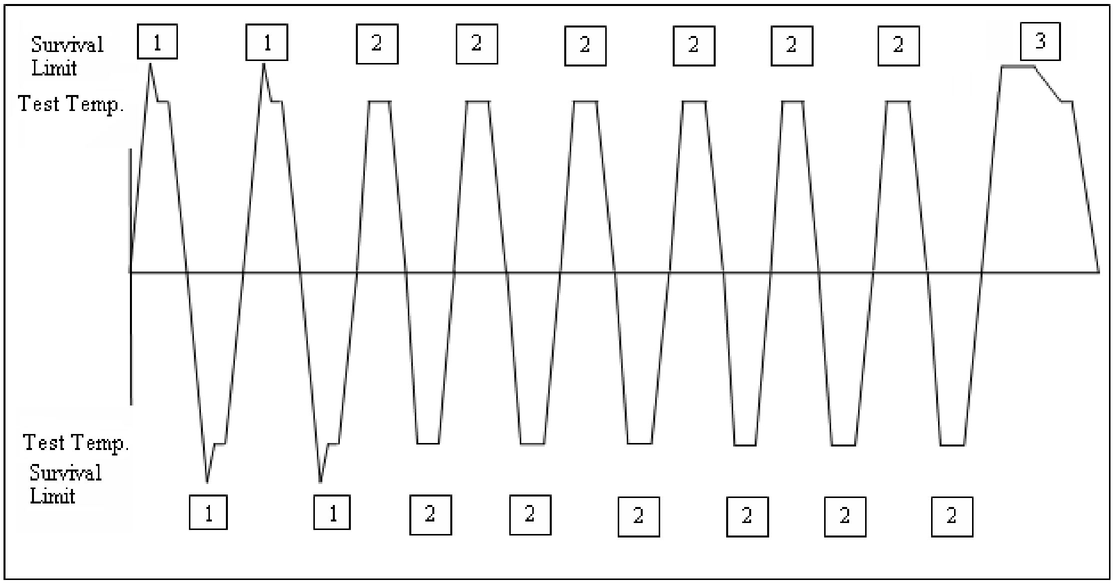
Soak time at each temperature: 4 hours, run Performance Test after soak.

Number of complete cycles:

Prototype Unit: 8 full cycles, start and end on hot cycle. Use Qualification Temperatures per Table 3-4 as the "Test Temperature."

Protoflight Unit: 8 full cycles, start and end on hot cycle. Use Qualification Temperatures per Table 3-4 as the "Test Temperature."

Flight / Copy / Spare Unit: 8 full cycles, start and end on hot cycle. Use Acceptance Temperatures per Table 3-4 as the "Test Temperature."



1 =	Achieve survival temp, stabilize 1 hour, return to test temperature, turn on, soak at test temperature 4 hours, run performance test.
2 =	Soak at test temperature 4 hours, run performance test
3 =	Bakeout phase

Figure 4-1 Thermal Vacuum Profile 8 Hot/Cold Cycles with Bakeout

4.5.7.5 Bakeout

MSS-410 The Sun sensor shall be baked-out prior to delivery to GSFC (see Figure 4-1). The bake-out performance shall be measured using a temperature-controlled Quartz Crystal Microbalance (TQCM) at chamber pressures below 1.0E-5 torr. The bake-out shall be performed at the hardware's maximum hardware survival temperature, unpowered, for 48 hours followed by a 12 hour period, powered, at the maximum operational temperature as defined in Table 3-4. The TQCM shall be maintained at -40C throughout the test to measure total outgassing of volatile outgassed condensables without the influence of water vapor. The TQCM must have a representative view of the hardware, preferably a vent.

MSS-411 The following test data shall be collected and delivered to GSFC: Chamber configuration (ie. chamber size, use of shrouds, TQCM location, cold finger/scavenger plate locations (if used), and general test setup), TQCM readings (taken as a minimum every 0.5 hours), hardware temperature, chamber/shroud temperature, TQCM temperature, and pressure

If the Contractor’s vacuum chamber uses a shroud to elevate and sustain an item’s temperature for bake-out, background TQCM measurements must be conducted before the bake-out with chamber in bake-out configuration in order to determine flight hardware contribution. Provision must be made to measure effectiveness of pump system. The value of a chamber's exit conductance is generally much lower than the rating of its pump alone. This is necessary to relate TQCM deposition rates to source outgassing rates

If the Contractor uses a bake-out box, the chamber should feature a shroud held at temperatures below the TQCM reading so as not to interfere with it, otherwise the bake-out box should feature a coldplate near the bake-out box vent to collect contaminants that would otherwise interfere with the TQCM readings. In such cases, knowledge of the chamber pump effectiveness is not necessary.

4.5.7.6 Outgassing Certification Requirements

MSS-415 Each flight item shall meet an outgassing certification requirement to be verified during thermal vacuum bakeout or thermal vacuum testing. The outgassing certification requirement shall be measured with a TQCM. The requirement shall be met when the outgassing rate is at or below 1.3e(-10) g/cm^2/s. The results of the test shall be submitted to the GPM Project for approval. The data set shall be recorded at least once every 30 minutes, for a minimum of 5 hours, during testing and shall contain, as a minimum, QCM data, temperature of hardware, QCM temperature, and chamber pressure. In addition, the chamber configuration and cold finger data shall be delivered with the results.

5 GROUND SUPPORT EQUIPMENT REQUIREMENTS

MSS-417 GSE for the MSS will consist of MSS stimulators and a stimulator control panel. The MSS stimulators and control panel should be capable of performing an aliveness test of the MSS when the MSS are mounted to the spacecraft. Each stimulator shall interface directly to each MSS. Each stimulator shall also interface to the control panel via harness to be provided by GSFC. The MSS stimulators shall be capable of operating in a vacuum environment of 1 x 10-5 torr and over the acceptance temperature range of -15 to +70°C.

MSS-418 The control panel shall be capable of individually controlling all MSS stimulators via an “ON/OFF” switch. When the stimulator is turned “ON” the MSS shall generate a minimum current output of 25% of the peak output. The control panel shall have a manual and remote interface. The control panel shall be capable of operating at ambient pressure and temperature.

APPENDIX A. ABBREVIATIONS AND ACRONYMS

Abbreviation/ Acronym	DEFINITION
AMS	Aerospace Material Specification
ANSI	American National Standards Institute
AO	Atomic Oxygen
atm	atmosphere
CLA	Coupled-Loads Analysis
C	Centigrade
CCB	Configuration Control Board
CCR	Configuration Change Request
CG	Center of Gravity
CM	Configuration Management
cm^2	Centimeters squared
CMO	Configuration Management Office
COTR	Contracting Officer Technical Representative
DA	Displacement Amplitude
dB	Decibel
dB/oct.	Decibel per octave
DC	Direct Current
ESD	Electrostatic Discharge
FOV	Field of View
g	grams
GEVS	General Environmental Verification Standards
GPM	Global Precipitation Measurement
GSFC	Goddard Space Flight Center
HDBK	Handbook
Hz	Hertz
kg	kilogram
km	kilometer
Lbs	pounds
mm	millimeter
MIL	Military
MSS	Medium Sun Sensor
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
Ohms/sq.	Ohms per square
SOW	Statement of Work
STD	Standard
TID	Total Ionizing Dose
TIM	Technical Interchange Meeting
VDA	Vapor Deposit Aluminum
W/m^2	Watts per meter squared